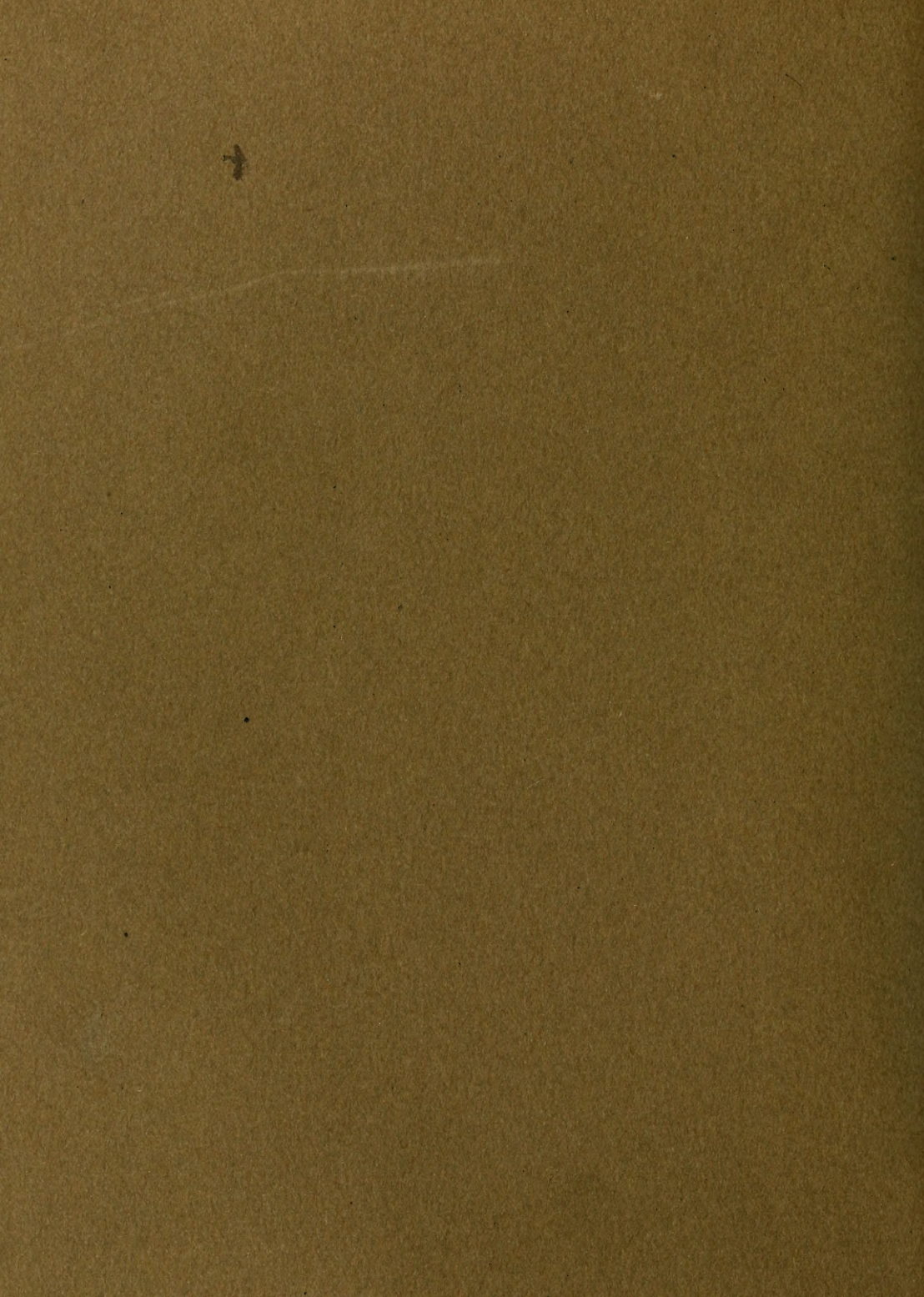


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SIXTEENTH MEMOIR.

ON THE CARBONIFEROUS XIPHOSUROUS FAUNA OF NORTH AMERICA.

141

W. P. HAY COLLECTION



(XVI.)

ON THE CARBONIFEROUS XIPHOSUROUS FAUNA OF NORTH AMERICA.

READ NOVEMBER 13, 1885.

BY A. S. PACKARD.

By the kindness of Messrs. R. D. Lacoe, of Pittston, Pa., and J. C. Carr, of Morris, Ill., I have been able to examine a most valuable collection of rare Xiphosuran fossils from Mazon Creek, Grundy County, Illinois, besides two specimens from the coal-beds of Pennsylvania. These have revealed the existence on this continent of two genera, hitherto confined to the European coal-measures, viz, *Cyclus* and *Belinurus*. From the Pennsylvanian coal-measures a new species of *Prestwichia* has been obtained, and it is probable that ultimately we shall find as many species of this family as there are in European strata.

Of still more interest is the discovery of remnants of cephalic limbs in *Cyclus* and *Prestwichia*, showing that in these animals the cephalic appendages were like those of the larval *Limulus*. It also appears that the ontogenetic development of *Limulus* is an epitome of that of the Xiphosura as a group. Furthermore, our studies have led us to restrict the Xiphosura to the three families of *Cyclidæ*, *Belinuridæ*, and *Limulidæ*, while certain upper Silurian forms referred by Woodward to the Eurypterida, and by Zittel placed among the Xiphosura, are, temporarily at least, referred to a new suborder, the *Synziphosura*, a group combining with features of its own, characteristics of the Xiphosura and some strong resemblances to the Trilobites.

Family CYCLIDÆ Packard.

CYCLUS AMERICANA Packard. Pl. V, figs. 1, 1a; VI, figs. 4, 4a.

Cyclus americana Pack., Amer. Naturalist, xix, 293, March, 1885.

In a nodule from Mazon Creek, Illinois, received from Mr. Lacoe, I recognize a species of this rather obscure genus, which has not before occurred in North America, though in Europe nine species have been described.

In form the animal is perfectly orbicular, the length being exactly equaled by the breadth. The body is regularly disk-shaped, flattened hemispherical, with the edge of the body broadly and regularly expanded, the margin being thin and flat, and apparently a little wider on the sides than on the anterior or posterior end. The inner edge of the rim is separated by an impressed line from the raised portions of the body-disk; the surface of the rim is not plain and smooth, but ornamented by a series of plate-like, squarish markings, apparently separated by a slight impressed line, and with a slightly marked, raised tubercle on each plate or scale.

There are no indications of segments either of the head or abdomen, nor are the limits between a head and abdominal region distinguishable, as is the case in *Cyclus jonesianus* Woodv.* There

* Contributions to British fossil Crustacea. By Henry Woodward, F. G. S., etc. Geol. Mag., vii, No. 12, pl. xxiii, Dec., 1870.

are, however, indications of four, and perhaps five, pairs of short, thick, cephalic appendages on the anterior third of the body. Unfortunately, they are not well preserved, the basal and distal portions not present, and the indications of joints indistinct; they are directed outwards from near the median line of the body, on each side of the intestine, the hindermost (6th) pair being directed somewhat obliquely outwards and backwards. In their position and relative distance apart they seem homologous with the cephalic limbs of the larval *Limulus*. The indications, slight as they are, lead us to suppose that they approached in general shape and relative size those of *Prestwichia*, reaching near but not passing beyond the edge of the cephalic shield. The distal portion of the limbs not being preserved, it is impossible to conjecture whether they were forcipate or not.*

Through the middle of the body, from near the anterior to the posterior margin, passes the cast of the digestive canal; it is swollen in front, the dilatation probably representing the proventriculus, and in outline the cast recalls that of the digestive canal of *Limulus*. Judging by analogy, the mouth was probably, as in the larval *Limulus*, situated well in front between the anterior pairs of appendages, and the oesophagus curved forward and upward from the mouth, while the vent was situated very near the hinder edge of the body.

There are no distinct traces of an abdominal region in the specimen, and it will be seen that in some of Dr. Woodward's figures there is also none. It is not probable that there was any spine in the genus, none being indicated in any of the figures or descriptions published.

Length of body, 14^{mm} ; breadth, 14^{mm} ; width of the flattened rim or margin, 1^{mm} . Locality, Mazon Creek. No. 218a, b. Collection of Mr. Lacoe.

Judging by our specimens and Dr. Woodward's figures, *Cyclus* if restored would have an orbicular body, more or less disk-like or hemispherical, with a cephalic region composed of six segments, which are not, however, indicated externally; this region had a thin margin, as in *Prestwichia* and *Limulus*. A pair of median ocelli were probably present, but no compound lateral eyes have yet been discovered. An abdominal region was slightly differentiated, and it was composed of three segments, the third representing that of the embryo *Limulus*, which in that form eventually becomes the caudal spine. The *Cyclus* was provided with six pairs of cephalic appendages, which were short, not reaching beyond the edge of the body. With these the animal could creep over the bottom of the shallow, muddy portions of the carboniferous sea. It is not improbable that there were two pairs of abdominal lamellated legs, adapted for respiration, short and broad, and not unlike those of the embryo *Limulus*. In fact, our conception of the form of the living *Cyclus* is that it was not much unlike the advanced embryo of *Limulus*, either in the stage represented in

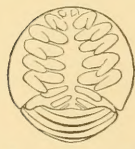


FIG. 8.—Embryo of *Limulus*; *Cyclus* stage.

Figs. 17 and 17a or 18, 18a, and perhaps 19 and 19a, of our memoir* of one of which (19a) Fig. 8 is a copy. At this stage of development the body of *Limulus* is hemispherical; seen from beneath the outline of the body is nearly orbicular, the abdominal region completing the circle. If *Limulus* were arrested at the stage of development when only three abdominal segments had appeared, and the development of the feet and claws had been accelerated and then hatched, it would be, so to speak, a *Cyclus*.

In our first memoir on the development of *Limulus* we adopted Dr. Woodward's view that *Cyclus* was a Xiphosuran. In 1868 Dr. Woodward stated: "We must differ from M. de Konink in referring this form to the Trilobites. If truly an adult, it must be placed near to *Apus*, with the other shield-bearing Phyllopods; if a larval form, it may have been the early stage of *Prestwichia*, or some other Limuloid of the coal-measures. Nor do we think it in the least probable that the shield of *Cyclus radialis* was flexible or contractile, its original segments being completely soldered together into one piece"; and in 1870 he adds that, from the recent inves-

* The Development of *Limulus polyphemus*, 1872, Pl. iv. Memoirs Bost. Soc. Nat. Hist., Vol. 1.

Since this article was sent to the printer, I have received, through the kindness of the author, Mr. B. N. Peach's "Further Researches among the Crustacea and Arachnida of the Carboniferous Rocks of the Scottish Border. Trans. Roy. Soc. Edinburgh, 1882." In this memoir Mr. Peach figures and briefly describes the limbs of *Cyclus*. "From the fact," he says, "that several of the Survey specimens exhibit limbs, the radiating lines of the sternum are most probably the divisions between the *coxæ*." Under *Cyclus radialis* Peach, he describes six triangular plates on each side, divided from each other by deep sulci, and converging upon an oral sternum. He also refers to "the jointed cylindrical limbs, the tips of which have not been observed."

tigations of Dr. Lockwood and myself, "these forms may indeed be the larval stages of *Prestwichia*, *Belinurus*, etc., the antetypes in Carboniferous times of the modern king crab." "Were it not for the large size of these fossils, some (*C. Harknessi*) measuring five lines in length, three and one-half lines in breadth, and three lines in height, we should be disposed to agree with Mr. Woodward; but, from what is known of the size and form of the freshly-hatched larvæ of *Limulus* and the Trilobites, I should infer that they were either the larvæ of some unknown genus of Limulidæ, or adult but embryonic forms. The larvæ of *Belinurus* and its allies, *Prestwichia* and *Euproops*, were, in all probability, closely allied in their form and size at the time of hatching to the larva of *Limulus*. But on comparing the deep hemispherical form of *Cyclus*, with the surface of the body deeply lobed over a more or less extent, with the embryo of *Limulus* before it is hatched (Pl. iv, figs. 18, 18a), we find a striking similarity; indeed, we seem to be dealing with a distinct embryonic type of Limulidæ. In *Cyclus* we have, in a late larval or possibly adult condition, that state of *Limulus* in which the body is deeply hemispherical, and the abdomen has just been differentiated from the rest of the body, while the deep transverse lobes of the yolk are not yet absorbed, as seen in Pl. iv, figs. 18, 18a, in the embryo of *Limulus*; the cardiac or median lobe being as distinctly marked in *Cyclus* as in the embryo of *Limulus*." (Development of *Limulus*, 1872, p. 189.)

After again reviewing the characters of *Cyclus*, with the specimen of *C. americanus* before us, we feel confirmed in the views above presented, and would regard *Cyclus* as the representative of a family of Xiphosura, being an adult form, and embryotypic, to coin a word, of a *Limulus*, while the *Belinuridæ* represent the larval *Limulus*.

Family DIPELTIDÆ Packard.

DIPELTIS DIPLDISCUS Packard. Pl. V, figs. 2, 2a.

Dipeltis diplodiscus Pack., Amer. Naturalist, xix, 293, March, 1885.

This name was proposed for a singular form which is not satisfactorily preserved, so that its exact relations are not readily determinable. The body is suborbicular, flattened, disk-like, sloping regularly and gradually from the median area to the edge; it is divided into two portions; the larger one to be regarded as anterior or the cephalic shield, and the other as posterior, constituting the abdomen (urosome). The edge of the body is very slightly marginate, not broadly so as in *Cyclus*; nor is the body distinctly trilobate, as in the *Belinuridæ* and *Limulidæ*, though unfortunately the median area of the cephalic shield is wanting. The integument is rather thin, showing no traces of segments; its surface may have had a few scattered small tubercles, at least there are slight indications of them. The surface is smooth and shining.

The cephalic shield is nearly twice as broad as long; the posterior lateral angle is well-rounded, with no sign of a lateral spine; in front the edge was probably obtusely rounded; the surface is slightly convex, the disk being low and flat, with no traces of a glabella; the hind edge of the shield is moderately concave, the limits between it and the urosome being clearly indicated by a slight, but distinct, regular, curvilinear suture.

The urosome is about three-fourths as long as, but equal in width to the cephalic shield. The front edge is somewhat arcuate, so that the projecting anterior-lateral angle is directed a little forward, and is quite free from the lateral angle of the cephalic shield, which turns away anteriorly from it, leaving a triangular space between the sides of the two regions. Posterior edge of the urosome regularly rounded, and with a slight margin. No traces of a caudal lobe or spine. Total length, 20^{mm}; total breadth, 20^{mm}; length of cephalic shield, 11^{mm}; breadth, 26^{mm}; length of urosome, 9^{mm}; breadth, 19.5^{mm}. Collection of R. D. Lacoe, 2017^{a, b, c} in a nodule from Mazon creek, Morris, Illinois.

This remarkable animal was disk-like in shape, composed of two regions, the head and abdomen or urosome, which are more distinctly separated than in the *Cyclidæ*; while there are no positive characters to separate it from this group, we would, for the present at least, refer it to an allied family, as it is orbicular, tailless, and consists of a broad, large cephalic shield, with a shorter, distinct, non-segmented urosome.

Family BELINURIDÆ Packard.

PRESTWICHIA DANÆ (Meek) Pl. V, figs. 3, 3^a; VI, 1, 1^a, 2, 2^a.*Bellinurus dane*, Meek and Worthen, Proc Acad. Nat. Sc., Phil., March 1865, Rt. Geol. Surv., Ill. ii, 395, 1866.*Prestwichia dana* Meek, Amer. Journ. Sc., 2d ser., xliii, 257, 1867.*Euproops dana*, Meek, Amer. Journ. Sc., xliii, 394, 1867.

Meek and Worthen, Rt. Geol. Surv. Ill., iii, 547, 1868.

Packard, Amer. Naturalist, March, 1885.

Head and abdomen (urosome), in the largest specimens, of the same length; in younger specimens the head is rather shorter than the abdomen; head about one-third as long as broad; genal spine about two-thirds as long as the head, and turning at nearly a right angle with the straight hinder edge of the cephalic shield; the spine as a whole is directed somewhat outward, nearly reaching a point about opposite the hinder edge of the third abdominal segment. Median lobe of the head or glabella, rather deeply excavated in front; at the bottom of the excavation are situated traces of the simple eyes, which have the same situation and shape as in *Limulus*. The small compound eyes are situated on the outer anterior angle made by the sides of the glabella and are of nearly the same relative size and in the same general situation as in the larval *Limulus*, though placed a little nearer the front margin. The eyes themselves are small, oval and prominent. The sides of the glabella are produced behind into a sharp spine, projecting backwards over the base of the abdomen.

The abdomen (or urosome) is from one-fourth to one-third broader than long, and is composed of eight distinct segments, including the caudal spine; the body of the abdomen is full, convex, and distinctly trilobate, the median or cardiac lobe being in general about a third narrower than the lateral lobes or pleura, and contracting in width towards the fifth segment. The sutures between the segments on the lateral lobes are very distinct, being raised, narrow ridges, prolonged into and forming the hinder edge of the long, sharp, slightly curved, lateral spines; of these lateral spines those on the first and second segments are the narrowest and most acute, that on the seventh the widest and most obtuse. In the cardiac lobe the third abdominal segment bears a high rounded tubercle, and there is one about twice as large on the sixth segment; those on the other segments are small, and in most of the specimens there are traces only of those on the third and sixth segments. The caudal spine (representing the eighth abdominal segment) is somewhat enlarged at the base; it is three-cornered in section, much as in *Limulus*, the surface is smooth, and it is about three-fourths as long as the abdomen.

Length of entire body (largest specimens), 60^{mm}; breadth, 53^{mm}.Length of cephalic shield, 24^{mm}; breadth, 53^{mm}.Length of lateral cephalic spine, 15^{mm}; breadth, near base, 3.5^{mm}.Length of abdomen (urosome) (not including the caudal spine), 23^{mm}; breadth 35^{mm}.Length of longest lateral abdominal spine, 6^{mm}.Length of caudal spine (telson), 15^{mm}.

The smallest specimen is 10^{mm} in length, and 12^{mm} in width, the caudal spine being less than one-half as long as the abdomen.

Description of the cephalic appendages.

In a nodule from Mazon Creek received from Mr. J. C. Carr, containing the remains of a specimen 55^{mm} across the shield (Pl. VI, figs. 2, 2^a), the cephalic appendages are more or less distinctly preserved. Of the first pair there are faint traces, the two small limbs lying parallel to each other and in the same position as in the larval *Limulus*, and of nearly the same proportions. The impressions of the succeeding limbs are distinct; the second third, fourth, and fifth pairs are of the same size, the fifth pair being perhaps a little longer, as the tips extend near the edge of the cephalic shield. All four pairs, *i. e.*, second to fifth, are chelate, the forceps being well developed and plainly visible in the third and fourth pairs, as these limbs are turned on their side; the fifth pair are undoubtedly chelate, but lie so that the outline is a simple point. The sixth pair differs

from the others in ending abruptly, the penultimate joint being long and of the same width throughout, and truncate at the distal end, where it gives rise to three small, sharp spines; there are also traces of a terminal minute joint from which two spines arise.

Length of second, third, fourth, and fifth pairs of legs, 16^{mm}.

Length of sixth pair, 17^{mm}.

Length of penultimate joint, 6^{mm}.

Thickness, 1^{mm}.

The legs are nearly identical in shape and length with those of the larva of *Limulus* described and figured in my Development of *Limulus* (Pl. 1, figs. 24^a, 25^a, and 23^d), though perhaps a little shorter, as they do not reach beyond the edge of the cephalic shield. It thus appears that in respect to its limbs as well as the shape and proportions of the body the *Prestwichia* resembles the larval *Limulus*. Thus *Limulus* in its development passes through a trilobitic, and afterwards a *Belinurid* stage.

PRESTWICHIA LONGISPINA Packard. Pl. V, fig. 4.

Euproöps longispina Pack., Amer. Naturalist, xix, 292. March, 1885.

The specimen upon which this species is founded is Mr. Lacoe's Nos. 215^{a-b} (impression and reverse), and was probably a molted skin (Pl. V, fig. 4). The body is considerably distorted by pressure, but the specific distinctness from *P. danae* is marked. The species will be readily distinguished by the very long genal spines; they extend nearly or quite to a point opposite the base of the caudal spine. The abdomen appears to be narrower in proportion to the cephalic shield than in *P. danae* while the genal spines are longer and narrower. The caudal spine is not well preserved.

Length of body (not including the caudal spine), 20^{mm}.

Length of head, 10^{mm}.

Length of abdomen, 10^{mm}.

Breadth of cephalic shield, 24^{mm}.

Breadth of abdomen, 13^{mm}.

Length of lateral cephalic spine, 13^{mm}.

Pittston, Pa., Butler mine, Nos. 215^{a-b}, collection of Mr. Lacoe.

In another larger specimen (Lacoe's No. 214^a, Pl. VI, fig. 3), the glabella, with the eyes, ocelli, and a part of the left lateral spine are preserved. Whether this is the same species as *P. longispina* I cannot tell with certainty, as the genal spines are not sufficiently well preserved, but provisionally it may be regarded as belonging to the species under consideration. The median lobe of the head is larger in proportion to the entire cephalic shield than in *P. danae*, and the eyes are nearer the lateral margin. The ocelli are situated on the median ridge of the lobe, somewhat behind the indentation between the lobes. The individual is without doubt a *Prestwichia* having the same number of abdominal segments as in *P. danae*.

Length of body (without the caudal spine), 30^{mm}.

Breadth of cephalic shield (estimated), 37^{mm}.

Length of cephalic shield, 17-18^{mm}.

Length of abdomen, 13^{mm}.

Breadth, 23^{mm}.

Estimated length of lateral cephalic spine, 15^{mm}.

Distance between the compound eyes, 17^{mm}.

Distance from ocelli to the front edge of body, 6^{mm}.

Distance from ocelli to hinder edge, 21^{mm}.

Oakwood Colliery, Wilkes Barre, Penn., collection of Mr. Lacoe, No. 214^a.

Regarding the position of the Illinois and Pennsylvania beds containing these fossils, Mr. Lacoe writes me: "The horizon of the Pennsylvania specimens of *Euproöps* is much higher than that of Mazon Creek. The latter is at the very base of the productive coal-measures in shale over the bottom seam of coal. The specimen from the Butler mine, Pittston, is from shale over coal 'E' (Mammoth vein), at the top of the lower productive coal-measures, about 300 feet above, and that from the Oakwood colliery is either from the same horizon or the bottom of the lower barren

measure next overlying it. The shaft from which it was taken, penetrating both, the exact position of the rock containing it could not be ascertained when we discovered it in the 'dump' or rock pile." Another specimen from Scotch Hill railroad cut, Pittston, Pa. Coal E. Lacoe's No. C. 3 $\frac{1}{2}$ -34.

Note on the validity of the Genus Euproöps.

By referring to the synonymy of *Prestwichia danae*, it will be seen that in 1865 it was referred by Messrs. Meek and Worthen to *Belinurus* for reasons given in *Palæontology*, vol. iii, of the Geological Survey of Illinois, p. 547. After the appearance of Dr. H. Woodward's paper read before the Geological Society of London in 1866* in which the genus *Prestwichia* was separated from *Belinurus*, the American form was referred to the new genus, *Prestwichia*, by Mr. Meek.

"At a later date (February, 1867), Mr Woodward published excellent figures in the *Quart. Jour. Geol. Soc.*, London, vol. xxiii, pl. 1, of the typical forms of both *Prestwichia* and *Belinurus*. From these it became evident that the peculiarities of the ridges of the head of the form on which he founded the genus *Prestwichia*, and which we had supposed probably due to some accident, really exist. Consequently, our type was regarded as being generically distinct, and the name *Euproöps* was proposed by one of us for it. Mr. Woodward, however, has since expressed the opinion that these differences are probably of scarcely more than specific value. (See *Geol. Mag.*, Jan, 1868, vol. v., p. 2.) Without professing to have made an especial study of the fossil *Crustacea*, on which Mr. Woodward is well known to be an eminently reliable authority, we would state that we can scarcely doubt that a comparison of *specimens* would lead him to the conclusion that the American form is at least subgenerically, if not generically, distinct from *Prestwichia*."

Finally the authors state that *Euproöps* differs from *Prestwichia* "not only in the position of the eyes, and the form and size of the glabella, or central area of the cephalothorax, but in the entire arrangement of the ridges and included areas of the same." Fig. 9. is from an electrotype of a cut published by Messrs. Meek & Worthen in illustration of their genus *Euproöps*.

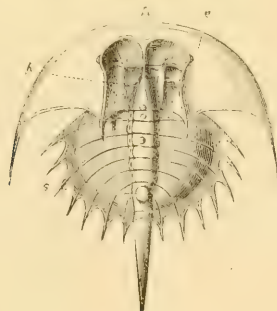


FIG. 9.—*Euproöps danae*. M. & W.
After Meek.

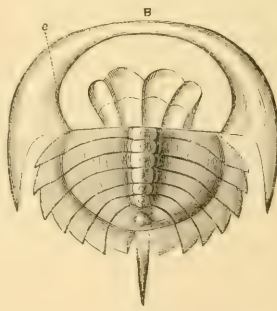


FIG. 10.—*Prestwichia rotundatus*. After
Woodward.

After repeated examinations of the series of about a dozen specimens from the collections of Messrs. Lacoe and Carr, I am at a loss to find valid characters for the genus *Euproöps*. In one example of *P. danae*, the glabella or middle lobe of the head, is distinctly divided into four sublobes, as in Woodward's figure of *P. rotundatus*; again the lack of lateral abdominal spines in his figure of *P. rotundatus* appears to me to be due to the imperfect state of preservation of the specimen, as some of the Illinois specimens do not show them; again the spines projecting from the sides of the glabella over the base of the abdomen, and represented as wanting in Woodward's figures, are wanting in certain Illinois specimens. As to the position of the compound eyes in *P. rotundatus* as represented in Woodward's figure, I am inclined to believe that the author and artist have been in error. I should not venture to make such a statement if in our Illinois and Pennsylvania specimens of *Prestwichia* and *Belinurus* the position of the eye were not invariably on the outer

*On some points in the structure of the Xiphosura, etc., *Quart. Journ. Geol. Soc.*, Feb. 1867.

angle of the glabella, in a position homologous with their situation in *Limulus*. I venture then to give the opinion that the apparent differences between *Prestwichia* and *Euproöps*, as stated by Messrs. Meek and Worthen, did not exist in nature, and that the genus *Prestwichia* was common to both Europe and North America during the Carboniferous Period. It is interesting in this connection to observe that the descendants of the *Belinuridae* in Europe, survive in the Solenhofen *Limuli* until the Jurassic, and disappear during the Cretaceous period, not to arise again on the western coasts of the old world, while in North America, so far as the record shows, the type became extinct during the Mesozoic and Tertiary, to reappear in the Quaternary and present period.

As regards the differences between *Belinurus* and *Prestwichia*, the former genus is the higher form, approximating *Limulus* in the consolidation of the eighth and ninth abdominal segments (forming the "abdomen" so regarded by Dr. Woodward) and in the very long caudal spine. In *Prestwichia* there is one abdominal segment less than in *Belinurus*, the short caudal spine forming the eighth.

BELINURUS LACOEÏ Packard. Pl. V, fig. 5.

Belinurus lacoei Pack., Amer. Naturalist, xix, 292, March, 1885.

Cephalic shield of the usual shape and length in proportion to the abdomen; the front margin as usual; the genal spine long, acute, extending obliquely outwards to a point parallel with one either a little behind the middle of the abdomen, or, in the older, larger specimens, nearly to a point parallel with the base of the caudal spine. The median lobe is, as usual, divided by the median line into two sublobes, so that the front edge of the entire lobe is indented in the middle; each sublobe contracts in width posteriorly behind the ocular or lateral angle bearing the compound eyes. The ocelli are not visible, but the compound eyes are partly preserved; they are small, and of the usual kidney shape. The abdomen is much more rounded than in the European *B. reginae*, being twice as broad as long. It consists (including the caudal spine) of nine segments. The median lobe is as broad at the end as at the base next to the thorax; there is a median tubercle on each segment, those on the third and last segment being larger than the others. The margin of the abdomen is broad and thin, giving rise to broad, acute, lateral spines. The caudal spine is very long and slender, a little swollen at the base; it is also triquetal, as in *Limulus*; it is nearly one-half longer than the body, *i. e.*, longer than the whole body by the length of the head, and ending in a fine, slender, needle-like point.

Length of the best preserved specimen 33^{mm} (including the caudal spine).

Length of body, 15^{mm}.

Length of caudal spine, 18^{mm}.

Length of cephalic shield, 7^{mm}; breadth at base of lateral spine, 16^{mm}.

Length of lateral spine, 4-5^{mm}.

Length of abdomen, 8^{mm}; breadth (not including the spines), 12^{mm}.

In nodules at Mazon Creek, Illinois; Nos. 210^h, 210ⁱ, 210^w, 212^{a, b}; 213^a, collection of Mr. Lacoe.

While having the same number of abdominal segments, this species, the first representative of the genus which has occurred in America, differs from *B. reginae* chiefly in the more rounded, less triangular outline of the abdomen, and in the smaller lateral abdominal spines. It is probable that in Dr. Woodward's figure of *B. reginae* the compound eyes are not correctly placed. In our specimens of *Belinurus* they have the same relative situation as in *Prestwichia dana* and *longispina*.

SYNOPSIS OF THE NORTH AMERICAN XIPHOSURA.

Suborder XIPHOSURA.

Family 1. CYCLIDÆ Pack.

Body disk-like, orbicular; abdomen composed of three segments, scarcely if at all differentiated from the cephalic shield; cephalic limbs nearly as in the larval *Limulus*; size small.

Genus *Cyclus* De Koninck, with the characters of the family.

Cyclus americanus Pack.

Family 2. DIPELTIDÆ Pack.

Body disk-like, elliptical; abdomen differentiated from the cephalic shield, smooth, no segments indicated.

Genus *Dipeltis* Packard, with the characters of the family.

Dipeltis diplodiscus Pack.

Family 3. BELINURIDÆ Pack.

Body limuloid in general shape; cephalic limbs as in the larval *Limulus*; shield with long slender genal spines; abdomen with the segments distinct; caudal spine short or long.

Genus *Prestwichia* Woodward. Eight abdominal segments, including the short caudal spine.

Prestwichia danie Meek.

Prestwichia longispina Pack.

Genus *Belinurus* König. Nine abdominal segments, including the very long, slender caudal spine; segments 7 and 8 consolidated.

Belinurus lacoëi Pack.

Family 4. LIMULIDÆ Zittel.

Body longer than broad; abdomen with segments consolidated; six pairs of abdominal limbs, five pairs having over a hundred pairs of gill-leaves.

Genus *Protolimulus* Packard.* Seven abdominal segments, including the large thick caudal spine.

Protolimulus eriensis (Williams).

Genus *Limulus* Müller. Cephalic limbs large; body longer than broad; abdomen with 9 segments; caudal spine longer than the body.

Limulus polyphemus (Linn.).†

* In a notice of a new Limuloid Crustacean from the Devonian, Amer. Journ. Sc., July, 1885, p. 45, Prof. H. S. Williams described an interesting Limuloid from the Devonian of Erie County, Pennsylvania (associated with typical Chemung fossils). It is described as *Prestwichia eriensis*, the author remarking that "its identification with *Prestwichia* must be regarded as provisional." He then adds: "The following characters exhibited in the specimen are regarded as generic and as locating it with genus *Prestwichia* of Woodward: (1) the elliptical head shield; (2) the genal spines which proceed backwards more directly than in any described species of the genus; (3) the thoracic-abdominal segments ankylosed to form a buckler, to which is attached (4) a long telson. The general outline of the whole animal resembles that of the modern *Limulus*." We have ventured, without having seen the specimen, to regard this form as probably a member of the family Limulidæ, and the forerunner of *Limulus*. It is certainly not a *Prestwichia*. The body is apparently longer than broad, and in outline it leaves a strong resemblance to the young *Limulus* after its first moult. This is seen in the shape of the abdomen and the caudal spine and in their relations to the rest of the body. It also seems probable that the abdominal segments were not free; in this respect it differs from the Belinuridæ, especially *Prestwichia*. Judging by the number of lateral spines, the abdomen was composed of 6 segments exclusive of the caudal spine, thus differing from *Prestwichia*, which has 7, also from *Limulus*, which has 8 pairs of lateral spines. We therefore venture to give it the generic name of *Protolimulus*, and to regard it as standing at the base of the family to which *Limulus* belongs. Its occurrence in the Devonian makes it a connecting link between the Upper Silurian *Neolimulus* and the Carboniferous and Jurassic Limuloids. We are indebted to Prof. Williams for the use of figures illustrating his *P. eriensis*.

† Besides the American species, there are three others living, viz, *L. moluccanus*; (East India) *L. longispina* Vander Hoven, Japan; *L. rotundicauda* Latr., Molucca Is. and Malacca.

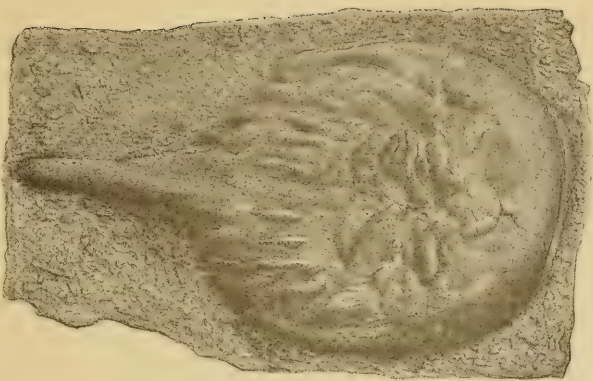


FIG. 11.—*Protolimnites eriensis* (Williams). A sandstone cast of the under surface, natural size.



FIG. 12.—Diagram of FIG. 11. A, cephalic shield; B, hypostome; C, genal spines; D, thoracic shield; E, pygidium; F, posterior margin of the hypostome; G, anterior margin of the hypostome; H, posterior margin of the thoracic shield; I, anterior margin of the thoracic shield; J, posterior margin of the pygidium; K, anterior margin of the pygidium; L, foliaceous terminations of the last gnathopods; M, position of the mouth.

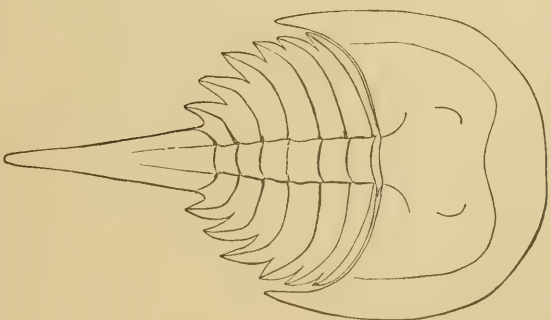


FIG. 13.—Theoretical diagram of the upper side.

PROTOLIMNITES ERIENSIS. After Williams.

The individual development of Limulus an epitome of that of the Xiphosura.

It is interesting to observe a clearly marked exemplification of the parallelism between the embryonic or ontogenetic development of *Limulus* and the geological succession as well as evolution of the suborder of which it is a type. We have already compared the orbiculo-hemispherical form of *Cyclus* with that of *Limulus* in the early stages of its embryonic life. The parallelism is striking. *Cyclus* may therefore be called an embryonic form. Again, in *Prestwichia* there is a close resemblance to *Limulus* shortly before it leaves the egg, in what we have called the trilobitic stage, a stage antecedent to the true larval stage, in which the abdominal segments become consolidated. *Prestwichia* may then be properly designated as a larval form, while *Cyclus* was an embryonic form. The latter genus embraces eleven species (ten in Europe), which exist in beds containing the species of *Belinuridae*. One cannot regard it as a retrograde form however, but as an embryonic Xiphosuran, whose development became accelerated, adapting it for active adult life. While the specimens of *Cyclus* have not yet shown the presence of compound lateral eyes, it is not impossible that the animal was provided with a pair of median simple eyes. This indicates that these were the primitive visual organs, and that the compound lateral eyes of the *Belinuridae* and *Limulidae* were secondary acquisitions, and that their simple eyes are legacies left by their *Cyclus*-like ancestors.

Cyclus, and perhaps *Dipeltis*, appear to represent *Agnostus* among Trilobites, and the similarity between all these simple types indicates a community of descent.

The Suborder SYNZIPHOSURA.

In the Upper Silurian beds of Europe have been revealed a number of exceedingly interesting forms, which appear to be Merostomata, but not true Xiphosura. They serve, on the one hand, to connect the Xiphosura with the Eurypterida, and also strongly suggest the community of origin of the Merostomata and Trilobita. They have been associated by Dr. Woodward with the Eurypterida,* but it seems to us, in the light of our present knowledge of the latter suborder and of the Xiphosura, that they are types of a third group or suborder. Perhaps the more aberrant form is *Bunodes* of Eichwald. All the genera have a caudal spine or telson. They are, besides *Bunodes*, *Hemiaspis* Woodward, *Pseudoniscus* Nieszkowski, *Exapinurus* Nieszk., and perhaps *Neolimulus* Woodward belongs with them, though the last form connects the Xiphosura and Synziphosura. They possess nearly as high an antiquity as the Eurypterida, but did not persist so long, as none have been discovered in the Devonian or Carboniferous rocks; hence we would infer that they were the forerunners of the Xiphosura rather than actual members of the group. In a word, the merostomatous ordinal tree divided into three main branches—i. e., the Eurypterida; the forms under consideration, which may be designated as the Synziphosura; and the genuine Xiphosura. In the Synziphosura the head forms a solid plate, with a slightly marked glabella or median lobe. Compound eyes are present in *Pseudoniscus*, and in *Exapinurus* the head is produced laterally into large genal spines. All have free uromeres or abdominal segments, and in all except *Bunodes*, in which the pleurum is shaped and marked as in Trilobites, the uromeres possess lateral projections or spines. None of them show traces of limbs or of simple eyes, and all are of moderate size.

The Synziphosura may be divided into three families, which may be diagnosed as follows (these groups appear to be, on the whole, equivalent in rank to the families of Trilobites):

1. Head rounded; no genal spine; abdomen divided into a "thorax," consisting of six trilobite-like segments, with diagonal pleural lines; "abdomen" of four segments, besides the large telson (*Bunodes* and *Exapinurus*).

Bunodidae Packard.

2. Head one-half broad as long, with several genal spines; abdomen triangular, with nine segments and a short telson (*Hemiaspis*).

Hemiaspidæ Zittel (restricted).

3. Body oval; head short; large compound eyes; nine abdominal segments besides a short telson (*Pseudoniscus*).

Pseudoniscidae Packard.

4. Head-shield short and broad; abdomen very broad, of nine segments besides the telson (*Neolimulus*).

Neolimulidae Packard.

* Quart. Journ. Geol. Soc., Feb., 1867.



FIG. 14.—nodes.
After Nieszkowski.



FIG. 15.—Bunodes.
After F. Schmidt



FIG. 16.—
Pseudoniscus.
After Nieszkowski.



FIG. 17.—Exapinurus. Af-
ter Nieszkowski.



FIG. 18.—Hemiaspis. Af-
ter Woodward.

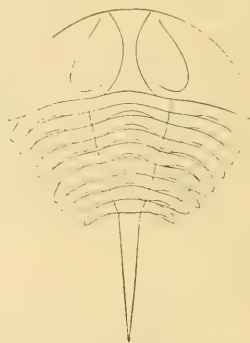


FIG. 19.—Neolimulus. After Woodward.

After the foregoing classification was mostly written out, we found that Professor Zittel, in his excellent *Handbuch der Palaeontologie*, Bd. I, 640, 1885, has divided the suborder of Xiphosura into two families:

1. *Hemiaspidae*, with the following genera: Bunodes (*Exapinurus* Nieszk.) subgenus *Hemiaspis*, *Pseudoniscus*, *Neolimulus*, *Belinurus*, and *Prestwichia*; while *Cyclus* and ? *Halycine* are regarded as genera of uncertain position.

2. *Limulidae*, *Limulus*.

It seems to us that this is scarcely a natural classification, and that it would be better to separate the Silurian forms mentioned above from the genuine Xiphosura, especially as we know nothing of the nature of their appendages, and to assign them, at least provisionally, to a group distinct from the genuine Xiphosura, especially since we now know something definite as to the nature of the cephalic appendages of *Cyclus* and *Prestwichia*, their resemblance to those of the existing *Limuli* being remarkably close. Certainly *Bunodes*, in which there are, according to F. Schmidt's late researches,* as stated and figured by Zittel, besides a four-jointed abdomen, a "thorax" composed of "six trilobite-like, movable segments," cannot well be allowed a position in the genuine Xiphosura. Moreover, the pleura of the single segments show a diagonal longitudinal ridge. This mark is a peculiarity of the pleura of some trilobites, and does not occur in any genuine Xiphosura, and aids in lending to *Bunodes* a trilobitic appearance.

If we separate *Bunodes* from the true Xiphosura, *Hemiaspis* will have to go with it, since it has a rounded cephalic shield, shaped somewhat as in *Bunodes*, but broader. We should not, with Zittel, regard it as a subgenus of *Bunodes*, because the "thoracic" segments have on the free sides no diagonal ridge, and the cephalic shield is ornamented with large spines, which perhaps indicate the head segments of the embryo. In both genera no eyes have yet been discovered. For the present we should, on the whole, regard the two genera as representing different families.

* F. Schmidt, *Miscellanea Silurica III. Die Crustaceen fauna der Eurypteruschichten von Rootziküll auf Oesel*. *Mém. de l'Acad. impér. de St. Péterbourg*, 7^e ser., xxxi, 1883.

Johannes Nieszkowski, *Zusätze zur Monographie der Trilobiten der Ostseeprovinzen nebst der Beschreibung einiger neuen obersilurischen Crustaceen*. Dorpat, 1859.

In *Pseudoniscus* we have another form which suggests a relationship to the Trilobites. Our figure is copied from Woodward's restoration. Nieszkonski, the original describer, remarked, "On the inner side of the shield we notice a place cut out, with the convexity looking outward, which should certainly be regarded as the outer edge of the eye."

The foregoing remarks are suggested by a study of the figures and descriptions of these remarkable forms, and as they are not based on a study of the specimens themselves, they will be taken only for what they are worth. But the fact remains that we have, side by side with the Eurypterida in the upper Silurian strata, a group which does not apparently belong to either the Eurypterida or genuine Xiphosura of the Carboniferous and later periods, and to which it seems best to assign, temporarily at least, an intermediate position. The group also is of great interest as serving to bridge over the gap between the Merostomata and Trilobita.

The following view will express the relations of the three suborders:

Order MEROSTOMATA.

1. *Eurypterida*. 2. *Synziphosura*. 3. *Xiphosura*.

HISTORICAL REVIEW.

I.—History of the *Xiphosura*.

In 1764 Gronovius, in the second fasciculus of his *Zoophylacium Gronovianum*, p. 220 (according to Van der Hoeven, for we have not seen this work), proposed the name *Xiphosura*. His work appeared in three fasciculi, bearing date 1763 to 1781, the second fasciculus dated 1764.

The name *Limulus* was first proposed by O. F. Müller (*Entomostraca*, 1785, p. 124), and adopted by Fabricius (*Ent. Syst.*, 487, 1893).

The name *Limulus polyphemus* (Linn.) was bestowed by Latreille in his *Histoire Naturelle des Crustacés et des Insectes*, tom. 4, p. 96, 1802.

In 1798 Latreille, in Cuvier's *Tableau élémentaire de l'Histoire Naturelle des Animaux*, placed the Limuli in the Crustacea, under the Monoculi.

Previous to 1806, the exact year we have not been able to ascertain, Latreille (*Suite à Buffon, Sonnini, Paris, 1798-1807*) assigned *Limulus* to the Entomostracan order 1 *Xiphosura* (fide Milne Edwards).

In 1806 Latreille (*Genera Crustaceorum et Insectorum*, i, 10) placed *Limulus* in order 1 *Xiphosura* of Legio 1 Entomostraca.

In the same year Duméril (*Zool. Anal.*) associated *Limulus* with *Caligus*, etc.

In 1809 W. Martin "gave a figure and short description of a *Limulus* crustacean from the coal measures, which he included with the Trilobita."

In 1810 Latreille (*Considérations générales*, etc.) assigned *Limulus* a place under the Entomostraca in Family 1, Clypeaces, Aspidiota, associating it with *Apus*, *Caligus*, and *Binoculus*. The term *Xiphosura* does not appear.

In 1835 Latreille (*Familles naturelles du Règne Animal*) places the *Xiphosura* between the Phyllopods, the Trilobites, and the Siphonostoma.

In 1828 Straus Durekheim (*Considérations générales sur l'anatomie comparée des Animaux articulés*) referred *Limulus* to a new order, *Gnathopoda*, forming the eighth order of Crustacea, which he placed between the Decapoda and Arachnida.

After the publication of his "Considerations," Straus Durekheim removed the *Gnathopoda* from the Crustacea to the Arachnida, as will be seen by the following extract from Lankester's "*Limulus* an Arachnid" (*Quart. Journ. Micr. Sc.*, 506, 1881):

Straus Durekheim maintained that *Limulus* should be classified with the Arachnida, but the publication of his views on the subject appears never to have taken a very definite or satisfactory form. In fact, the only record of Straus Durekheim's teaching on this subject which I can find is in the French translation of Meckel's "General Treatise on Comparative Anatomy." M. M. Reister and Alph. Sanson carried out this translation and added many notes in the form of appendices to each volume. At the end (p. 497) of the sixth volume, which bears the date 1829-1830, there is a note headed "Sur l'appareil locomoteur passif des Arachnides," which appears to be an abstract of a memoir "On the

Comparative Anatomy of the Arachnida," read to the Academy of Sciences June 1, 1829, but never, I believe, published. M. Straus Dürckheim communicated its contents to MM. Reister and Sanson. From this note I submit a few extracts. The authors commence:

"La classe des Arachnides, dans laquelle M. Straus comprend le genre *Limule*, formant à lui-seul un ordre désigné sous le nom de *Gnathopodes* et dont il isole les *Pycnogonides* qu'il renvoie aux Crustacées, offre dans la disposition de son squelette et des muscles qui en meuvent les diverses pièces, des particularités tellement tranchées qu'on ne peut, y méconnaître un type différent. C'est de ce squelette que sont tirés les traits principaux propres à caractériser la classe des Arachnides en général, et qui consiste dans la disposition des pattes rayonnant sur un sternum commun, dans la présence d'un sternum cartilagineux intérieur, dans l'absence d'antennes."

The Arachnida are then divided into three orders, "les pulmonaires, les branchifères, et les trachéens," but it is not explained whether the term "*gnathopodes*" is to be regarded as simply a synonym of the order "*branchifères*."

With regard to the internal sternum, the citation of the views of M. Straus runs as follows:

"Dans l'intérieur du thorax de tous les *Arachnides*, à l'exception peut-être des *Acarides* dont la plupart des espèces sont trop petites pour qu'on puisse les disséquer et connaître leur organisation, on trouve une pièce cartilagineuse diversement configurée suivant les familles, et placée dans le thorax au dessus du sternum, cette pièce, à laquelle convient le nom de sternum intérieur, est maintenue librement par le moyen de plusieurs muscles qui ce conduit de différents points de sa surface sur le bouclier, ou sur le sternum extérieur auquel ils se fixent. Elle sert en outre de point d'insertion à un certain nombre de muscles des pattes."

In Cuvier's Règne Animal, nouv. édit., 1829 (tom. iv), the group named by Latreille, *Pacilopoda*, is characterized and described as the second order of Entomostraca. The order consists of two families: Xiphosura (genus *Limulus*) and Siphonostoma (*Caligus*, *Argulus*, etc.). As the group *Pacilopoda*, by its founder, includes the parasitic Copepoda besides *Limulus*, it seems advisable to drop it, retaining the term Xiphosura, which has never been applied to any other animal than *Limulus* and its allies. On p. 46 he remarks: "De cet ordre de crustacés on arrive à la classe des ARACHNIDES, dont l'organisation, en général, approche beaucoup de celle des *Limulus*."

In 1830 Milne-Edwards (Ann. des Sc. Nat., xx, mars 1830) adopted the order Xiphosura, placing it below the Siphonostomata.

In 1834 Milne-Edwards (Hist. Nat. des Crustacés) retained the order Xiphosura.

Straus-Dürckheim's views were more explicit than supposed by Professor Lankester, as in Straus's work, published in 1842, entitled "Traité pratique et théorique d'Anatomie comparative," etc., vol. 2, 169, we find the following statement:

J'ai formé l'ordre des *Gnathopodes* avec le seul genre *Limulus*. Ces singuliers animaux ont été rangés parmi les Crustacés par tous les naturalistes qui, ne connaissant pas leur organisation, les plaçaient dans cette classe par cela seul qu'ils ont des branchies, tandis qu'ils s'en distinguent essentiellement par le reste de leur organisation, en offrant les plus grandes analogies avec les Arachnides! et l'existence des branchies ne saurait à elle seule constituer un caractère suffisant pour les éloigner de ces derniers, vu que dans cette classe les organes de la respiration n'ont plus cette grande prépondérance sur les autres appareils du corps, pour les tenir sous leur dépendance, comme cela a lieu chez les vertébrés; ce qui est prouvé par l'analogie qui existe entre les Arachnides pulmonaires et les trachéens, qu'on ne saurait séparer.

Dana (1852) in his Crustacea of the U. S. Exploring Expedition, proposed the order *Merostomata* for *Limulus* exclusively, which he places in the tribe *Limuloidea*. He makes no mention of the Eurypteridae. The *Pacilopoda* in Dana's system forms the first suborder of *Cormostomata*, and include the *Ergasilioidea*, *Caligoidea*, and *Lernæoidea*.

In 1866 Hæckel (Generelle Morphologie der Organismen, ii, lxxxix) regarded the *Trilobita* as forming the third legion of Branchiopoda. They are in his system succeeded by the sixth subclass of Crustacea, the *Pacilopoda*, which embraces the two legions of *Xiphosura* and *Gigantostomata*. The latter name is proposed for the *Pterygotidae* and *Eurypteridae* alone. As Hæckel's *Gigantostomata* appears to be exactly synonymous with Dana's *Merostomata* as amended by Woodward, the awkward, meaningless term, which has never been defined, should be discarded. It has, however, been adopted by Dohrn in 1871 (Zur Embryologie und Morphologie des *Limulus Polyphemus*, Jena. Zeits., vi, 1871), and by Claus, though in a greatly extended, and it seems to us an unwarrantable, sense. Dohrn remarks:

Limulus is nearest related to the *Gigantostomata*. Both appear to be related to the *Trilobites*, though this relationship cannot be established in all the details. The morphological and genealogical relations of these three families to the Crustacea are not such as to be surely determined; perhaps they will remain always doubtful. That they are related to the Arachnida we are not, as the matter now stands, in a position to allow. So it only remains for us to put these three groups under a common name, for which I might adopt Hæckel's expression "*Gigantostomata*," and let them take their place in the system with (*neben*) the Crustacea.

II.—Affinities of the Eurypterida to the Xiphosura (*Limulida*) and the formation of the order Merostomata as at present received.

In 1825 Dr. J. E. De Kay described and figured the first (an American) species of Eurypterus known (*E. remipes*), and referred it to the class Crustacea and to the order Branchiopoda.

In 1844 L. Agassiz remarked of Pterygotus:

I am rather inclined to believe that this singular animal will become the type of a family intermediate between the Trilobites and the Entomostracans in which perhaps, the Eurypteri and the Eidothea will some day be included.

We have given on pp. 177, 178 of our essay on "The Development of Limulus" (1872) a history of the views of James Hall, Salter, and others, especially the first-named, who proved that the Eurypterida belonged to the same order as Limulus.

In 1866 in his elaborate "Monograph of the British fossil Crustacea, belonging to the order Mesostomata," Dr. H. Woodward formally united the Eurypterida in the same order with Limulus, remarking:

Having long been convinced of the propriety of expressing in some suitable manner the correctness of the conclusions of Professors Agassiz and James Hall as to the close affinity existing between the Eurypterida and the Xiphosura, and being fully persuaded at the same time that they naturally form two distinct although closely related groups, I have ventured to unite them in the Order MEROSTOMATA—a name proposed by Dr. J. D. Dana for the recent king-crabs only, retaining at the same time the names Eurypterida and Xiphosura as suborders.

In 1872 we adopted this classification, which seems eminently natural, and has since been adopted by a number of leading zoologists.

In 1868 Claus (Grundzüge der Zoologie) characterized the order Pæcilopoda, but in the third edition of this work (1876) the Pæcilopoda (restricted to Limulus), though placed between the fourth order, Phyllopoda, and fifth order, Arthrostraca, in the Crustacea, and at the end of the Phyllopoda, are associated with the Trilobita in a special group to which no special rank is assigned.

III.—Transfer of the Merostomata (with the Trilobita) to an independent class.

In 1869 Huxley stated in the "Academy" (November 13):

The Xiphosura have such close morphological relations with the Arachnids, and especially with the oldest known Arachnid, Scorpio, that I cannot doubt the existence of a genetic connection between the two groups.

In 1871 Prof. E. Van Beneden (Comptes Rendus de la Soc. Ent. Belgique, October 14, 1871; Annals and Mag. Nat. Hist., January, 1872) remarked:

The Limuli are not Crustacea; they have nothing in common with the Phyllopoda, and their embryonic development presents the greatest analogy with that of the scorpions and other Arachnida, from which they cannot be separated. * * * The Trilobites, as well as the Eurypterida and the Pæcilopoda, must be separated from the class Crustacea, and form with the Scorpionida and the other Arachnida a distinct branch, the origin of which has still to be ascertained.

In 1872 A. Milne Edwards (Annales des Sc. Nat.) published his important researches on the internal anatomy of Limulus, which showed that Limulus essentially differs from the Crustacea. In the same year we attempted to show the close affinities of Trilobites to Limulus.

In 1876, according to Claus's own statement (Annals and Mag., July, 1886, p. 56), referring to his change of views as to the position of Limulus, he remarks:

Even in the work entitled "Untersuchungen über die genealogische Grundlage des Crustaceensystems" (Vienna, 1876) I adhered to the views of those who, like Straus-Dürckheim, regard Limulus and Branchiate Gigantostraca as allied to the air-breathing Arachnoidea, and the latter as having proceeded from the former, although, having regard to the possibility of a still undemonstrated Nauplius stage, I considered it probable that the common origin of the true Crustacea was rather after than before the Nauplius period of the Stem-Crustacean. In the case of Limulus and the Scorpions I also asserted the homology both of the six pairs of limbs of the cephalothorax, and, with reference to the developmental history, of the six pairs of limbs of the preabdomen, of which the second pair represents the comb-like organ of the Scorpions, while the following four pairs immediately undergo retrogression (p. 110). In the "Grundzüge der Zoologie" of the year 1880 I went so much further as to divide the Branchiata, or Crustacea, *sensu latiori*, into Encrustacea (with the Entomostraca and Malacostraca) and Gigantostraca (with no certain traces of the Nauplius stage), and accordingly I affirmed expressly of the Tracheata that in opposition to the more ancient Branchiata they "were not referable to a unitary origin, since the Arachnoidea, which are derivable from the Gigantostraca, stand opposite to the Myriapoda and Insecta, which are united by a closer affinity" (p. 515).

In 1885 and 1886 (Annals and Mag. Nat. Hist., July, 1886) Claus regarded the Gigantostrea as a class intermediate between the Crustacea and Arachnida. He thinks that the Arachnida descended from the Gigantostrea, adding, "I by no means affirm the *Arachnoidal nature of Limulus*."

In 1879, in our Text-book of Zoology, as the result of Milne Edwards's researches, we divided the Crustacea into two subclasses, the *Neocarida* and *Palæocarida*, the latter group comprising the Merostomata and Trilobita. In a previous paper we had shown the close homologies of the eye of Trilobites to the compound eyes of Limulus.

In April, 1881, Mr. C. D. Walcott (Bull. Mus. Comp. Zool., viii, No. 90, p. 209), under the class Pœcilopoda, places two subclasses, viz, Merostomata and Palæadæ (Trilobita), giving definitions of the groups.

In 1881, in his article "Limulus an Arachnid" (Quart. Journ. Micr. Sc.) Prof. E. Ray Lankester proposed the term *Hæmatobranchia*, which he regarded as the equivalent of Merostomata. This group of the class Arachnida, as understood by Lankester, embraces the three orders: 1, Trilobita; 2, Eurypterida; and 3, Xiphosura.

In 1885 (Embryology of Limulus Polyphemus, III, Proc. Am. Phil. Soc., January, 1885), we referred Limulus, with the Eurypterida and Trilobita, to a class by themselves.

In 1885 Mr. J. S. Kingsley associated the Limulus with the Arachnids as a group by themselves, to which he gave the name *Acera* (Science News and Quart. Journ. Micr. Sc.).

In 1886, in the 5th edition of our Text-book of Zoology, we suggested the term *Podostomata* for the class comprising the two orders Merostomata and Trilobita.

IV.—The class *Podostomata*.

It thus appears that while at the present date (1886) A. Milne Edwards, E. Van Beneden, and E. R. Lancaster regard Limulus and its allied forms as belonging to the Arachnida, and J. S. Kingsley associates the Limulus and the Arachnida in a group by themselves under the name *Acera*, the present writer and Professor Claus regard the Merostomata with the Trilobites as forming a class intermediate between the Arachnida and Crustacea.

We have endeavored to show that the names Pœcilopoda and Gigantostrea have been applied in such different senses by different authors that they cannot well be retained for the Merostomata and Trilobita taken together in the sense we advocate. We have therefore proposed the term *Podostomata* for this class of Arthropoda. It is derived from πούς, ποδός, foot, and στόμα, mouth, in allusion to the foot-like or ambulatory nature of the cephalic appendages which surround the mouth in a manner characteristic of the group.

The class Podostomata may be defined as a group of Arthropods, in which the cephalic (Limulus) or cephalo-thoracic (Trilobites) appendages are in the form of legs, *i. e.*, ambulatory appendages, usually ending in forceps, or large claws (chelæ), which in the sole living representative of the class are arranged in an incomplete circle around the mouth; the basal joint of each leg is spiny, so as to aid in the retention and partial mastication of the food. No functional antennæ, mandibles, or maxillæ. Eyes both compound and simple. Respiration by branchiæ attached to the abdominal appendages, which are broad and lamellate in Merostomata and probably cylindrical with narrow gills in Trilobita. The brain (procerebrum) supplying nerves to the eyes alone; the nerves to the cephalic or cephalo-thoracic appendages originating from an œsophageal ring; the ventral cord ensheathed by a ventral arterial system more perfectly developed than in insects or scorpions; coxal glands highly developed, with no external opening in the adult. This class differs from the Arachnida, among other characters, in having no functional cheliceres ("mandibles") or pedipalps ("maxillæ"); in the cephalic appendages either ending in large claws or forceps, or simple, the terminal joint not bearing a pair of minute claws or unguis like those of Arachnida and Insecta, enabling their possessors to climb as well as walk. Podostomata have no urinary tubes. Limulus undergoes a slight metamorphosis, while in Trilobites the adult differs from the larva in having a greater number of thoracic segments.

From the Crustacea the Podostomata differ in the lack of functional antennæ and mouth parts; in the brain innervating the eyes (compound and simple) alone; in the shape of the head and of the pygidium or abdominal shield, and in the arterial coat enveloping the ventral nervous cord.

The Podostomata are divided into two orders:

I. *Merostomata* with three suborders, *Xiphosura*, *Synziphosura*, and *Eurypterida*.

II. *Trilobita*.

Explanation of Plate V.

Fig. 1. *Cyclus americanus* Pack. $\times \frac{1}{2}$. 1a, lateral view restored. $\times \frac{1}{2}$.

Fig. 2. *Dipellis diplodiscus* Pack. Natural size; 2a, the same restored. $\times \frac{1}{2}$.

Fig. 3. *Prestwichia danæ* Meek. Natural size; restored; dorsal view.

Fig. 3a. *Prestwichia danæ* Meek. Natural size; partly restored; ventral view.

Fig. 4. *Prestwichia longispina* Pack. Partly restored. $\times \frac{1}{2}$.

Fig. 5. *Belinurus lacœi* Pack. Partly restored. $\times 2$.

All the figures on this plate drawn by Dr. J. S. Kingsley, with corrections by the author.

Explanation of Plate VI.

Fig. 1. *Prestwichia danæ*, showing the limbs; 1a, the reverse.

Fig. 2. *Prestwichia danæ*, showing the interior; 2a, the same, another specimen.

Fig. 3. *Prestwichia longispina*, natural size.

Fig. 4. *Cyclus americana*, natural size; 4a, reverse of the same.

From photographs taken by Mr. R. L. P. Mason, Providence, R. I.

Explanation of Plate VII.

Fig. 1. *Palæocaris typus* M. & W., natural size.

Fig. 2. *Palæocaris typus* M. & W., natural size.

Fig. 3. *Anthrapalæmon gracilis* M. & W., carapace laterally flattened.

Fig. 4. *Anthrapalæmon gracilis* M. & W., from a small specimen without the carapace.

Fig. 5. *Anthrapalæmon gracilis* M. & W., carapace wanting.

Fig. 6. *Anthrapalæmon gracilis* M. & W., carapace wanting.

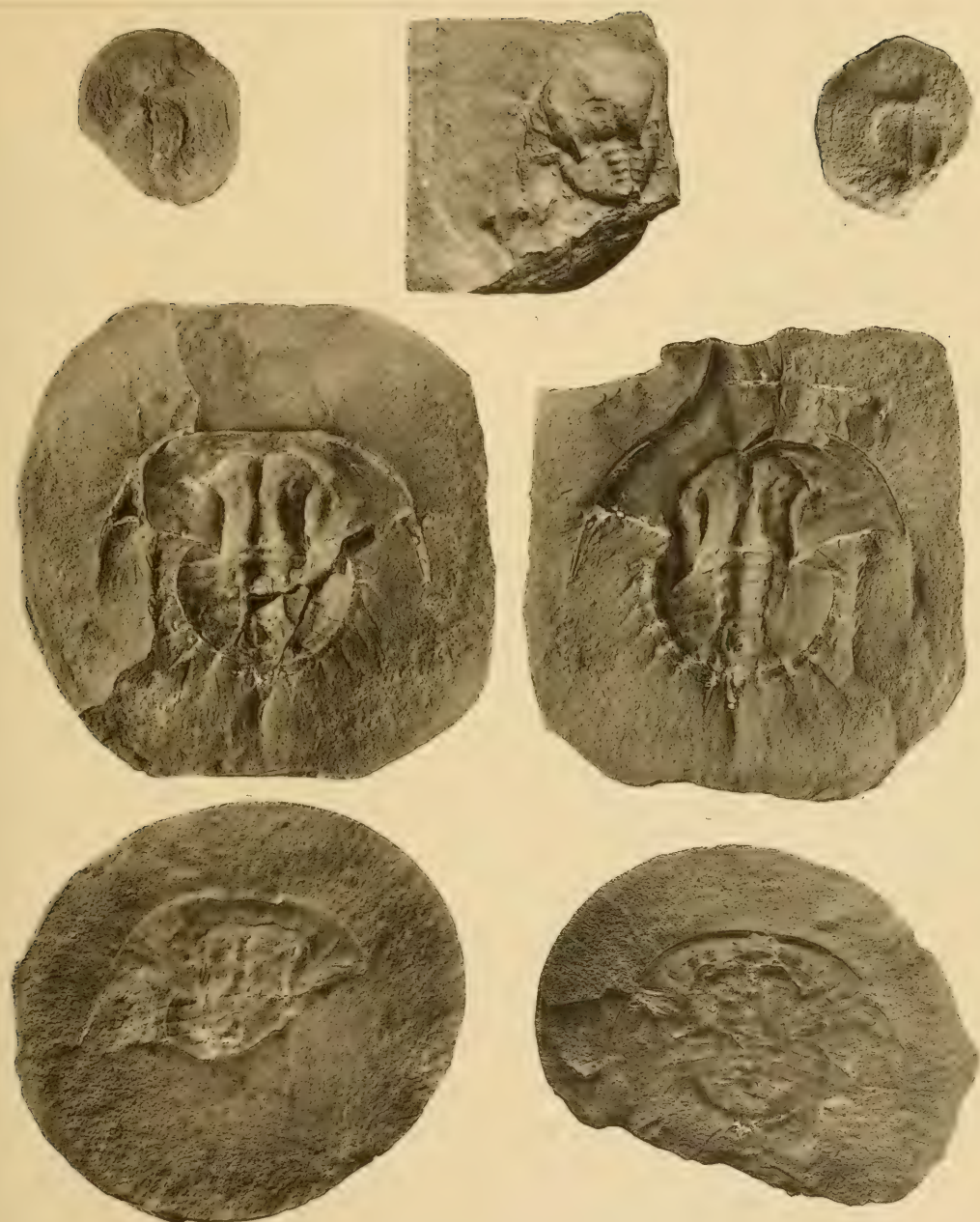
All the figures of natural size and from photographs taken by Mr. F. O. Draper, Pawtucket, R. I.



J. S. Kingsley, sc.

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CARBONIFEROUS XIPHOSEIRA.



FIGS. 1, 2. *PRESTWICHIA DANÆ*; 3. *P. LONGISPINA*; 4. *CYCLUS AMERICANUS*



FIGS. 1, 2. *PALÆOCARIS TYPUS*; 3—6. *ANTHRAPALÆMON GRACILIS*

FROM PHOTOGRAPHS BY F. D. DRAPER.

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